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Mechanical Behaviour of Geopolymer Concrete under Ambient Curing

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Abstract- Utilisation of fly ash and Ground Granulated Blast Slag as an alternative material in concrete reduces the use of OPC in concrete. Evolution of geopolymer concrete cured at ambient temperature broadens its suitability and applicability to concrete based structures. This paper presents the mix proportions and outcome of an experimental study on the density and compressive strength of geopolymer concrete. Fly ash was used as a base material which was made to react with sodium hydroxide and sodium silicate solution to act as a binder for fine and coarse aggregate. Ground Granulated Blast Slag was replaced in different proportions to fly ash to enhance various properties of concrete. The concrete was subjected to curing at ambient temperature. Based on the study carried out, replacement of GGBS in fly ash up to 50% produced better mechanical properties.

Keywords- **Concrete, Geopolymer, Ground Granulated Blast Slag, Ambient Curing**

I. INTRODUCTION

Geopolymers are formed by the alkaline activation of aluminosilicate materials like fly ash, blast furnace slag etc [i]. Low-calcium fly ash-based geopolymer concrete has been reported to have excellent compressive strength, good acid resistance and resistance to sulphate attack [ii]. Geopolymer concrete do not require any water for matrix bonding, instead the alkaline solution react with Silicon and Aluminium present in the fly ash. Geopolymer is synthesized by mixing aluminosilicate-reactive material with strong alkali solutions, such as sodium hydroxide (NaOH), potassium hydroxide (KOH), sodium silicate or potassium silicate. The mixture can be cured at room temperature or temperature cured. Three common types of geopolymer are the polysialate Al–O–Si chain, polysialate siloxo Al–O–Si–Si chain and polysialate disiloxo Al–O–Si–Si–Si chain. In the synthesis of geopolymers, NaOH was found to significantly affect both the compressive strength and structure of geopolymers. The NaOH concentration in the aqueous phase of the geopolymeric system acts on the dissolution process, as well as on the bonding of solid particles in the final structure [iii]. It was found that high pH (pH＝14) was the optimal condition for geopolymerisation. The effect of composition and temperature on the properties of fly ash- and kaolinte-based geopolymers was studied, and it was concluded that the water content, the fly ash/kaolinte ratio, as well as the type of metal silicate used had a substantial effect on the final properties of geopolymer [iv].

The polymerisation process is generally accelerated in the higher temperature than ambient. Fly ash based geopolymers produced in ambient temperature achieves lower strength in the early days as compared to heat cured samples but in ambient curing the compressive strength increases as the age of concrete increases from 7 days to 28 days. The compressive strength of hot cured fly ash based geopolymer concrete does not increase substantially after 7 days [v]. The tensile strength of the geopolymer concrete increases with increase in the total aggregate content [vi] .

In terms of practical application it is very important to cure at ambient temperature. Hence this study aimed to produce geopolymer concrete based on fly ash and ground granulated blast slag with improved engineering properties.

II. EXPERIMENTAL DETAILS

A. Materials

Fly ash used for geopolymer concrete was low calcium fly ash (ASTM class F) which was obtained from Mettur Thermal power plant. Ground granulated blast slag was collected from nearest steel plant. The chemical composition of fly ash and GGBS was shown in Table 1.The fine aggregate used was natural sand (river sand) and was sieved with 4.75mm sieve to remove larger particles. The coarse aggregate used was a HBG metal which was available from local crusher with nominal maximum size of 10, 12 and 20mm that met the Indian standard specifications. Sodium Hydroxide was obtained in the form of pellets and is made to solution using water. Sodium silicate was obtained in the form of gel which was made to mix with sodium hydroxide. The sodium silicate solution with a ratio of SiO_2 to Na_2O is 2.0 was used.

B. Preparation of solution for Geopolymer concrete

Sodium hydroxide which was obtained as a pellet was made to a solution using tap water. Based on the previous works the molarity for sodium hydroxide was set to 14M [ix]. To prepare sodium hydroxide solution of 14 Molarity (14M), 560 gram of sodium hydroxide pellets was dissolved in one litre of tap water. Reaction of sodium hydroxide with water liberates heat. Sodium silicate gel is added to the prepared

sodium hydroxide solution after 15 minutes and is well stirred to form a complete mix.

TABLE 1
CHEMICAL COMPOSITION OF FLY ASH AND GGBS

sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	LOI
Fly ash (%)	54.3	29.7	10.98	1.91	0.89	0.45	0.53	0.38	0.86
GGBS (%)	32.1	14.4	0.66	43.5	3.99	0.24	0.33	4.69	0.09

C. Mix Proportioning

Based on the previous works the concrete mixtures was proportioned [xiv]. Fly ash was replaced in the range of 10% to 50% by GGBS of total binder content. The ratio of sodium silicate to sodium hydroxide was 2.5 and kept constant. The ratio of alkaline activator to the total binder was made to keep constant at 0.4. The above ratio was used for all the replacement mixtures. Water was added if workability was required. Table.2 explains the number of mixes used for casting the specimen.

TABLE 2
QUANTITIES OF INGREDIENTS OF CONVENTIONAL CONCRETE MIX

Mix	Cement Kg/m^3	Fly Ash Kg/m^3	GGBS Kg/m^3	Water Kg/m^3	NaOH Solution Kg/m^3	Na_2SiO_3 Solution Kg/m^3	Fine Aggregate Kg/m^3	Coarse Aggregate Kg/m^3	Alkaline liquid to Fly Ash Ratio
M1	350	--	--	185	--	--	483	1081	--
M2	--	350	--	--	40	100	483	1081	0.4
M3	--	315	35	--	40	100	483	1081	0.4
M4	--	280	70	--	40	100	483	1081	0.4
M5	--	245	105	--	40	100	483	1081	0.4
M6	--	210	140	--	40	100	483	1081	0.4
M7	--	175	175	--	40	100	483	1081	0.4

* *For Geopolymer concrete additional water is added for workability alone*

D. Mixing and Casting

The alkaline activator was prepared a day before mixing of the solution. First the fly ash, slag and the aggregates were dry mixed for 2-3 minutes. The prepared alkaline activator was then mixed with dry mix and wet mixing was done for about 5 minutes. Extra water was only when workability was demanded. Then the geopolymer concrete was poured into the moulds and was compacted in a vibrating table machine. Then the top surface is well finished. The sizes of the moulds used were cube (150mm x 150mm x 150mm), cylinder - (150mm dia and 300 mm height), prism - (500 mm x 100 mm x 100 mm).

E. Curing

The moulds were then demoulded after 24 hours and were left in room temperature until testing. The average temperature recorded during the curing period of the specimen was 23°C. Conventional Cement concrete specimen are demoulded after 24 hours and allowed to curing.

II. **RESULT AND DISCUSSIONS**

A. Compressive Strength

The compression test on cubes and cylinders were conducted according to Indian Standard specifications (IS: 516 – 1959). Figure.1 shows the compressive strength of various mixes.

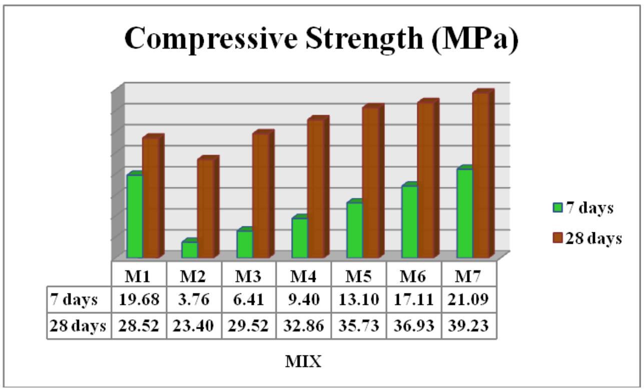

Figure.1 Compressive Strength of various Mixes

B. Split Tensile Strength

A direct measurement of ensuring tensile strength of concrete is difficult. One of the indirect tension test methods is split tension test. The split tensile strength test was carried out on the compression testing machine. The casting and testing of the specimens were done as per IS 5816: 1999. Figure.2 demonstrates the split tensile strength of concrete for different mixes.

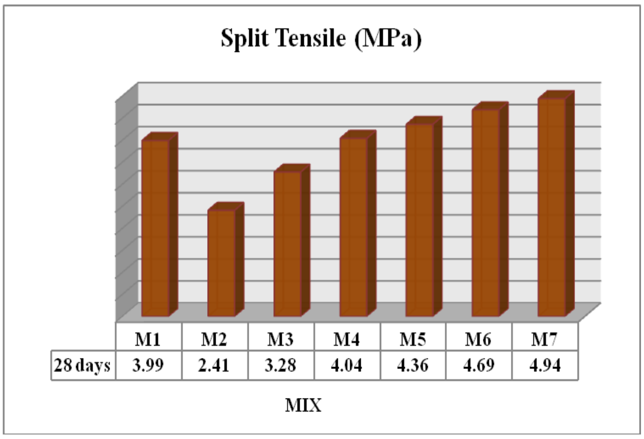

Figure.2 Split Tensile strength for various mixes

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C. *Modulus of Rupture*

The extreme fibre stress calculated at the failure of specimen is called Modulus of rupture. It is also an indirect measure of predicting the tensile strength of concrete. Flexural strength test was conducted as per recommendations IS: 516 – 1959. Figure.3 shows the split tensile strength for various mixes.

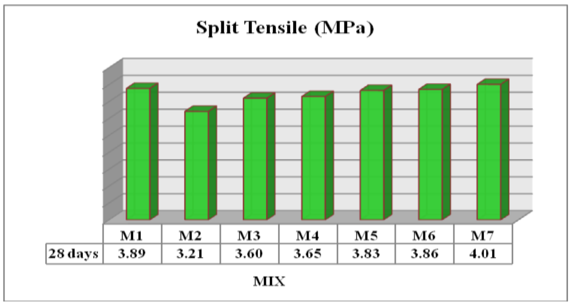

Figure.3 Split Tensile strength for various mixes

IV. CONCLUSION

From the above mentioned experimental investigation following conclusions has been determined

- Addtion of slag in the mixture decreases the setting time and the presence of slag in the mix reduces the slump value thereby increasing the degree of workability.
- Due to the constant increase in the prercentage of slag content there was a constant increase in compressive strength was observed.
- Compressive strength of Mix M7 (50% replacement of slag) concrete shows better result than conventional concrete and other mixes.
- Split tensile strength and modulus of rupture of mix M7 (50% replacement of slag) concrete given better result when compared with all the mixes.

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